

## REVERSIBLE DRIVING APPARATUS FOR PCU PUMPS

### FIELD OF THE INVENTION

[0001] The present invention relates to an accessory driving apparatus for an aircraft system, and more particularly to a reversible apparatus for driving a propeller control unit (PCU) pump of an aircraft system.

### BACKGROUND OF THE INVENTION

[0002] Today's propeller aircraft generally include variable pitch propeller systems. Typically, a variable pitch propeller system for aircraft includes a plurality of propeller blades extending radially from a central hub, an engine for rotating the hub and propeller blades, and a pitch actuating system that pivots the propeller blades about their longitudinal axis to vary the angle (pitch) of the blades with respect to the approaching airflow. The pitch actuating system is hydraulically controlled by a propeller control unit (PCU) and is hydraulically powered by a PCU pump of an aircraft system.

[0003] PCU pumps are usually operatively connected to and thus driven by propeller shafts of the aircraft system. PCU pumps are conventionally unidirectional, either clockwise or counter-clockwise. The selective use of clockwise and counter-clockwise PCU pumps is determined in accordance with the propeller shafts to which the PCU pumps are to be operatively connected.

[0004] In a multi-propeller aircraft system, it has been considered to be advantageous to the aircraft system performance that the propellers of the aircraft rotate in

different directions, namely some propellers rotate in a clockwise direction and the remaining propellers rotate in a counter-clockwise direction. This can be achieved by providing either a clockwise or counter-clockwise propeller gearbox to couple the particular propeller shaft to each engine which drives that propeller. In order to meet with this type of demand, aircraft engine manufacturers are required to provide both clockwise and counter-clockwise PCU pumps for a single design of aircraft system, which increases manufacturing costs due to the need for double the pump inventory.

[0005] Reversible rotary pumps have been well known and used in other industries. Those reversible rotary pumps, however, are usually relatively complicated and therefore are not suitable for application in the aircraft industry. PCU pumps for an aircraft system are required to be reliable in performance and light in weight.

[0006] Therefore, there is a need for an apparatus for driving a unidirectional PCU pump of an aircraft system which overcomes the problems in the prior art.

#### **SUMMARY OF THE INVENTION**

[0007] One object of the present invention is to provide an apparatus for driving a PCU pump of an aircraft system which is suitable for obtaining rotation power from a driving shaft rotating in either rotational direction, to drive the pump in a predetermined direction of rotation.

[0008] In accordance with one aspect of the present invention, there is a method provided for obtaining

rotational power from a driving shaft to drive a unidirectional pump of an aircraft system. The method comprises providing a driven shaft disposed at an angle with respect to the driving shaft, and operatively connected to the unidirectional pump; and providing a gear set for transferring rotational power from the driving shaft to the driven shaft, the gear set being selectively arranged in first and second configurations, depending on a rotational direction of the driving shaft, in order to ensure that a rotational direction of the driven shaft satisfies a predetermined rotational direction of the unidirectional pump.

[0009] Preferably, the method further comprises determining a first position on the driving shaft for mounting a first bevel gear when the first configuration is selected such that the first bevel gear meshes with the bevel pinion on the driven shaft at a first point of the bevel pinion; and determining a second position on the driving shaft for mounting the second bevel gear when the second configuration is selected such that the second bevel gear meshes with the bevel pinion on the driven shaft at a second point of the bevel pinion diametrically opposed to the first point.

[0010] In accordance with another aspect of the present invention there is an accessory driving apparatus provided for an aircraft system which comprises a driving shaft adapted to provide rotational power and a driven shaft adapted to be driven by the driving shaft and to be connected to an accessory unit to be driven. The driven shaft is positioned at an angle with respect to the driving

shaft. A gear set is provided for transferring rotational power from the driving shaft to the driven shaft, and the gear set is adapted for selective arrangement in first and second configurations in order to permit the driving shaft to rotate in either rotational direction without affecting a predetermined rotational direction of the driven shaft.

**[0011]** In accordance with a further aspect of the present invention, an apparatus is provided for reversibly driving a propeller control unit (PCU) pump of an aircraft system comprising a driven shaft adapted to be driven by a propeller shaft and to be connected to the PCU pump, the driven shaft being positioned at an angle substantially perpendicular with respect to the propeller shaft. The apparatus is further provided with a gear set which includes a first bevel gear selectively mounted to the propeller shaft in a first axial position thereof, a second bevel gear selectively mounted to the propeller shaft in a second axial position thereof and a bevel pinion mounted to the driven shaft at an end thereof for selectively gearing into the first or second bevel gears. The selection of mounting the first and second bevel gears to the propeller shaft is based on a rotational direction of the propeller shaft, in order to ensure that the driven shaft rotates in a predetermined rotational direction.

**[0012]** The present invention overcomes the shortcomings of the prior art with a simple solution in which the driven bevel pinion mounted on the PCU pump shaft is positioned at a right angle to a driving bevel gear being mounted on the propeller shaft in selective positions such that the same PCU pump can be used regardless of the rotational direction

of the propeller shaft. Therefore, the present invention advantageously provides the flexibility of replacing a clockwise propeller gearbox with a counter-clockwise propeller gearbox or vice versa, as required, without changing the PCU pump. Thus, only a minimum inventory is required because the same PCU pumps, the same bevel pinions and the same propeller shaft configurations can be used for aircraft systems having propellers rotating in either or both directions. There is only one extra bevel gear needed, which will be further explained with reference to an embodiment described hereinafter.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0013] Having thus generally described the nature of the present invention, reference will now be made to the accompanying drawings, showing by way of illustration a preferred embodiment thereof, in which:

[0014] Fig. 1 is a schematic illustration of an aircraft system, for hydraulically adjusting the pitch of propeller blades, which incorporates one embodiment of the present invention;

[0015] Fig. 2 is a cross-sectional view of a section of an aircraft system incorporating the embodiment of the present invention illustrated in Fig. 1, showing a first configuration of an apparatus for driving a propeller controlled unit (PCU) pump;

[0016] Fig. 3 is a cross-sectional view of the section of the aircraft system incorporating the embodiment of the present invention illustrated in Fig. 1 showing a second

configuration of the apparatus for driving a propeller controlled PCU pump; and

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[0017] Referring to Figs. 1, 2 and 3, an apparatus generally indicated by numeral 10 according to one preferred embodiment of the present invention is provided for obtaining rotational power from a driving shaft, for example a propeller shaft 12, to drive an accessory unit of the aircraft system, for example a unidirectional propeller control unit (PCU) pump 14. The propeller shaft 12, a central axis of which is indicated by numeral 13, extends at one end thereof from a propeller gearbox or so-called reduction gearbox (RGB) 16 and is coupled at the other end thereof with the propeller assembly 18. The RGB 16 is typically mounted to, for example, a gas turbine engine 20 of the aircraft(not shown) such that the propeller shaft 12 transmits power from the engine 20 to the propeller assembly 18. The direction of rotation of the propeller assembly 18 and the propeller shaft 12 is determined by use of a clockwise (CW) RGB or a counter-clockwise (CCW) RGB mounted to the same engine 20. PCU pump 14 is intended to provide hydraulic power for a propeller control unit (PCU) 22 to controllably actuate a pivot movement of propeller blades 24 about their longitudinal axis 26 for pitch (angle) adjustment. The PCU pump 14 can be driven in rotation only in one predetermined direction, and therefore the apparatus 10 according to the present invention is adapted to ensure that predetermined direction of rotation of the PCU pump 14 regardless of the direction of rotation of the propeller shaft 12.

**[0018]** Apparatus 10 includes a driven shaft 28 which is operatively connected to the PCU pump 14 for driving the pump in rotation in the predetermined direction. The driven shaft 28 can be either an integrated part of the PCU pump 14 or an additional part to be attached to the PCU pump 14. The PCU pump 14 is mounted to a stationary structure 30 of the aircraft system in a manner such that the driven shaft 28 is disposed at an angle with respect to the propeller shaft 12 which is rotatably supported by the same stationary structure 30 by means of a bearing assembly 32. The driven shaft 28 is preferably disposed substantially perpendicular to the propeller shaft 12. The reason for this will be further discussed hereinafter.

**[0019]** Apparatus 10 preferably includes a first configuration 34 and a second configuration 36 which are selectively used, as illustrated by the broken lines 38, 40 in Fig. 1, depending on a rotational direction of the propeller shaft 12. In particular, a first bevel gear 42 is mounted to the propeller shaft 12 at a first axial position thereof when the first configuration of the apparatus 10 is selected (illustrated in Fig. 2). A third bevel gear, for example a bevel pinion 46 in this embodiment, is mounted to the driven shaft 28, preferably at the free end thereof. The bevel angles of the respective gear 42 and the pinion 46 are determined such that the bevel gear 42 gears well into the bevel pinion 46 at a first gearing point 48 of the bevel pinion 46. Therefore, in the first configuration, the apparatus 10 transfers the torque and rotational movement from the propeller shaft 12 to the driven shaft 28 for driving the

PCU pump 14 in rotation through the first gearing point 48 between the first bevel gear 42 and the bevel pinion 46.

**[0020]** Apparatus 10 further includes a second bevel gear 44 which is preferably mounted to the propeller shaft 12 in a second axial position as illustrated in Fig. 3, when the second configuration of the apparatus 10 is selected. The bevel angles of the respective second gear 44 and the pinion 46 are determined such that the second bevel gear 44 gears well into the bevel pinion 46 at a second gearing point 50 of the pinion 46. The first and second gearing points 48, 50 are disposed diametrically opposite on the pinion 46.

**[0021]** When the propeller shaft 12 rotates in one direction, for example in the CW direction, as shown in Fig. 2, the first configuration of apparatus 10 is selected. The driven shaft 28 is driven by the propeller shaft 12 in CW rotation, by means of the first bevel gear 42 and the bevel pinion 46. The tangential linear velocity of the both bevel gear 42 and bevel pinion 46 at the first gearing point 48, is in a direction perpendicular to the surface of the paper of the drawing and towards the viewer at the front of the paper, because the bevel gear 42 rotates in the CW direction together with the propeller shaft 12. Thus, the pinion 46 is driven to rotate together with the driven shaft 28 in the direction of rotation indicated by arrow R in Fig. 2.

**[0022]** When the propeller shaft 12 rotates in the CCW direction and the second configuration of the apparatus 10 is selected, as illustrated in Fig. 3, the PCU pump 14 and



the driven shaft 28 are driven to rotate by the propeller shaft 12 rotating in CCW rotation by means of the second bevel gear 44 and the bevel pinion 46. The tangential linear velocity of both bevel gear 44 and bevel pinion 46 at the second gearing point 50, is also perpendicular to the surface of the paper of the drawing, but directs away from the viewer into the paper, because the second bevel gear 44 rotates together with the propeller shaft 12 in the CCW direction. Thus, the pinion 46 is driven to rotate together with the driven shaft 28 in the direction of rotation indicated by the arrow R in Fig. 3, the same direction of rotation as shown in Fig. 2. Therefore, appropriate selection of the configurations of apparatus 10 of the present invention will ensure that the PCU pump 14 or other accessory devices which would be connected thereto, rotates in the predetermined direction of rotation, regardless of the direction of rotation of the driving shaft, such as the propeller shaft 12 in this embodiment.

**[0023]** It is understood that when the driven shaft 28 is disposed substantially perpendicular to the propeller shaft 12, the bevel angles of the first and second bevel gears 42, 44 can be substantially the same. This not only benefits a simpler configuration but also provides substantially the same speed and substantially equal power transmission efficiency from the propeller shaft 12 to the driven shaft 28 whenever the first or the second configuration of the apparatus 10 is selected. In application, straight teeth gearing produces relatively more noise and provides limited transmission efficiency.

Therefore in the aircraft industry, gears with spiral teeth are widely used.

**[0024]** It should also be noted that although the first and second bevel gears 42, 44 can be made substantially identical when the driven shaft 28 is disposed substantially perpendicular to the propeller shaft 12, separate inventories of the respective first and second bevel gears 42, 44 are still preferred because the first and second bevel gears 42, 44 are preferably configured slightly differently for their different mounting positions.

**[0025]** It should be further noted that in this embodiment, although the bevel gears are selectively mounted in first and second axial positions on the driving shaft, it is applicable to selectively mount the bevel gears in first and second axial position on the driven shaft in other applications, when the existing configuration requires such an arrangement. This alternative arrangement will achieve substantially the same result.

**[0026]** It should be still further noted that the apparatus of the present invention can be used in applications where the driving shaft rotates in a predetermined rotational direction but the driven shaft is to be driven in either direction of rotation, as required. In that application, the selection of the configurations of the apparatus depends on the direction of rotation of the driven shaft, as required.

[0027] In order to conveniently mount the selective bevel gears 42, 44 to the propeller shaft 12, the propeller shaft 12 preferably includes appropriate configurations. For example, the diameter of a section thereof for mounting the first bevel gear 42 is slightly smaller than the diameter of the section thereof for mounting the second bevel gear 44, but has a small radial extending stopper 52 such that the first bevel gear 42 can be restrained at the first axial position on the propeller shaft 12 when the first configuration is selected and the second bevel gear 44 can pass over the radial stop 52 to the second axial position on the propeller shaft 12 where the bevel gear 44 is axially restrained by the bearing assembly 32 when the second configuration is selected. Thus, the central openings of the respective first and second bevel gears 42, 44 have different diameters in accordance with the diameters of the propeller shaft sections in the respective first and second axial positions. Keys and groove structures may be needed for circumferentially restraining the relative bevel gears 42, 44 and pinion 46 on the respective shafts for transferring torque therebetween. Furthermore, appropriate securing means are provided for securing the bearing assembly 32 and either bevel gear 42 or bevel gear 44 in place. Those securing means are well known in the prior art and a number of alternative configurations and elements can be used to achieve the selective mounting of the bevel gears 42, 44 to the propeller shaft 12, and the mounting of the pinion 46 to the driven shaft 28.

[0028] Modifications and improvements to the above-described embodiment of the present invention may become apparent to those skilled in the art. The foregoing description is intended to be exemplary rather than limiting. The scope of the present invention is therefore intended to be limited solely by the scope of the appended claims.